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Regional Groundwater Flow Assessment in a Site Specific Portion of Peshawar Valley In Pakistan

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Abstract

A research study was conducted in selected sites of Peshawar for development of ground water mapping by utilization of Resistivity survey with the help of Terrameter SAS 1000/4000 along with 4 electrodes and other accessories for data collection, 20 sites were selected for data collection in various parts of Peshawar where data was collected with standard electrode array of Schlumberger array with 300 m spacing on each side of the instrument. Coordinates and elevation from mean sea level of each site were recorded with global positioning system (GPS). Arc GIS was utilized for geo referenced map of the study area where the survey points were plotted. Another tool Surfer was utilized for contours development for ground water levels. The analysis of resistivity data were executed with the help of 1X1D software on the basis of which the ground water level were calculated which were also compared with existing water table of the area in surroundings and were in good match. The results indicate that the area has different pattern of ground water flow as the ground water in University Campus was toward Pakistan Forest Institute area as the elevation of ground water was at a depth of 339 m as compare to Works directorate of Agriculture University where the elevation was 334 m while in Malakandhir Farm the direction of flow was toward New Professor Colony Site where elevation of ground water was at a height of 319 m as compare to rest of profiles in the area which elevation was 323 m with respect to mean sea level for Biotechnology profile 359 m from mean sea level for Veterinary hospital and 351 m for military profile. In Hayatabad the flow pattern was also different as the in Phase 3 the ground water flow was toward Phase 3 civil quarters with an elevation of 339 m form mean sea level which was lower than rest of the site in the area while in Phase 7 the ground water flow was toward Behram Market which was at an elevation of 335 m from mean sea level. The study indicates that among all the surveyed sites the critical zone with low water table was Hayatabad where further detailed study of ground water exploration along with artificial recharge techniques were recommended to restore the depletion of water table.

Keywords: Terrameter, Schlumberger Electrode Configuration, 1X1D, Ground water flow, Artificial Recharge

INTRODUCTION

Groundwater is one of the remarkably vital freshwater resources and its mounting demand for agriculture, it multipurpose uses as for domestic and industrial purpose ranks it as of deliberate significance. Comprehensive estimates show that groundwater contain one sixth of the total freshwater resources accessible in the world (Hafiz.2002). Water is not consistently strewn both temporally and specially, therefore its droughts and floods can create severe situation. Water accessibility in Pakistan has also vanished down from 5104 m^3per capita in 1950`s to about 1000 m^3per capita in 2001 (WRI, 2001). As a result the state has merely 22 million hectares of irrigated land out of 31 million hectares of cultivable acreage accessible (PSY, 2008). Moreover, main portion of the country lies in the baked to semi-arid weather and rainfall ranges from a little of 150 mm in the southern to more than 750 mm in the northern west part of the country (Bakhsh and Awan, 2002). In Pakistan the major groundwater resource is in the irrigated areas of the Indus Basin followed by the areas outside Indus Basin as The Indus plain contains about 31 Mha cultivable domains, which is underlain by sand alluvium to a significant depth (MINFAL, 2008). Water is stored in the alluvial deposits habitually under liberated environment. These aquifers pay raise water for irrigation and help out the farmers overcome shortages and irregularities in the canal water supplies. The increase rate of private tube wells since 1990 to 2000 has increased at the rate of 60%in Punjab, 10% in Sindh, 63%in Khyber Pukhtunhwa, and 43% in Baluchistan (PSY, 2008).

According to the Ministry of Food, Agriculture and Livestock, Government of Pakistan, Islamabad, the entire number of private tube wells in the state has been expected to be about 1 million (MINFAL, 2008).A noteworthy fraction of the irrigated area in the country is also totally reliant on the groundwater or is irrigated by conjunctive use of groundwater with the surface water supplies. In a number of canal command areas where surface water supplies are inadequate, irrigation by means of groundwater of minor quality is consequential in the reduction of groundwater resources further the crisis of secondary salinization (Sarwar and Eggers, 2006).

Groundwater is flexible resource which can be utilized at whatever time requisite, and which has the additional advantage of no evaporation losses. The Khyber Pakhtunkhwa province lies in the four broad geological units namely, metamorphic and igneous rocks of the northern mountains, Mesozoic rocks of the southeastern part, Tertiary rocks of the southeastern part and upper Tertiary. The main groundwater resources in the Province are the alluvial plains and many valleys, which are intermountain basins of tectonic origin. The rainfall recharge was estimated 0.7 MAF (7% of rainfall over a sub-catchment). The average flows for the period 1988-2000 was 6.68 MAF (ACE and Halcrow, 2001). In this Province, recharges from the canal system were worked out 1.0 MAF (15% of 6.7 MAF). The groundwater recharges include returns from irrigation application, other return flows, sub-surface inflows and recharge from rivers. The recharge from the return irrigation flows was assessed 1 MAF (15% of 6.5 MAF) and other return flows (15% of 0.88 MAF) were worked out to be 0.13 MAF. The total groundwater resource of the Khyber Pakhtunkhwa was assessed as 3.11 MAF. Groundwater of Khyber Pakhtunkhwa Province has been studied by M/S ACE & Halcrow (2001). Only a small percentage of the exploitable groundwater resource has so far been developed by dug-wells, tubewells or otherwise. In this Province, the existing groundwater abstraction through 13 000 private and 491 public tubewells is 2 MAF per year.

Due to lack of groundwater management in the public sector, everybody can set up a tube well wherever in his land and can utilize no matter what amount of water he desires any time with no thought of the harmful effect of his action on the resource. However if pumping rate is equivalent to recharge rate for a sufficient period of time, the water table depth will become stable somewhere below the ground surface. If somewhere the extraction of groundwater is in excess to the possible recharge rate, the removal of the aquifer will result in the accelerated depletion of the groundwater level with an untenable lowering of the water table. Also, the rough groundwater development and pumping through private tubewells has started showing stress on the aquifer in the form of excessive draw-down and deterioration of groundwater quality. This requires serious attention and the urgent adoption of measures for proper groundwater management. As yet no such study was conducted for monitoring and management of ground water in study area so the study was planned to design with following key objectives.

Objectives

Specific objectives of the study were to

- Development of ground water mapping in study area on the basis of resistivity survey
- Identification of critical water table zone on the basis of water table depth
- Suggestions on the basis of the research study findings

MATERIALS AND METHODS

Site Selection

The sites for the proposed study were chosen at different locations in Peshawar where the resistivity survey was conducted in accordance with desired objectives to be achieved. Twenty sites were selected for this purpose from the Satellite Image obtained. This map is showing locations of tube wells with Circle and profile surveyed with plus sign. In addition to other detail that is given in the form of table from the grid survey conducted the require data was acquired. The data was then interpreted to be utilized to get the desired results.

Ground Water Modeling

The research study was conducted in selected sites of Peshawar using Terrameter SAS1000/4000 along with other accessories such as GPS and other physical tools. The research study objectives were achieved through the following operational activities.

Data Collection

The data was collected in the selected sites by utilizing resistivity survey in addition to the fundamental instrument of Terrameter SAS 1000/4000. This instrument contains four set of electrodes, distance measuring tools and GPS. The standard electrode configuration of Schlumberger array was adopted with its suitability for the study area.

The basic equation of Apparent Resistivity used in Schlumberger Electrode Configuration is as given below

$$K = \pi(\frac{AB}{2})^2 - (\frac{MN}{2})^2 \ /MN \ldots\ldots\ldots\ldots 1$$

Where, K represents geometric factor which vary with respect to depth. π: A mathematical constant equal to 3.14, AB/2 half spacing of current electrode (m). MN/2 Half spacing of potential electrode spacing (m) MN Total spacing of potential electrode spacing (m). To calculate Apparent Resistivity the following equation was used.

$$\text{Apparent resistivity} = k.R \ \ldots\ldots\ldots\ldots\ldots 2$$

Where k: Represents geometric factor which vary with respect to depth, R Resistance recorded by the Instrument. (Ohm)

Analysis of Resistivity Data

The resistivity values estimated from the measurement were analyzed through 1D inversion technique software (1X1D). The resistivity data was analyzed by fitting the acquired field data with least root mean square error between the synthetic data generated from the model and the actual data themselves.

Identification of Ground Water Levels

On the basis of resistivity data which was analyzed by the model the ground water levels for the surveyed sites were estimated on the basis of resistivity values which were matched with standard resistivity values of some common geological formations which is given below and thus the water table/saturated zone containing water was identified. The local depth to water table with respect to ground surface and universal water table depths with respect to the mean sea level for the given latitude and longitude of a specific location is given in table below.

Ground Water Mapping in the Study Area

The co-ordinates of each site from the survey were taken using GPS including altitude, latitude and longitude of each point. The subsurface depth of each point under consideration was achieved by subtracting the given depth of the water table from its elevation on surface of ground just above it. The points taken by GPS were super imposed over the map which was acquired from Google Earth, a free program for public use. The subsurface strata changes in longitudinal as well as in transitional sections of soil having equal resistivity or Isoresistivity lines from the given water table depth were linked universally to other lines using a computer Software of SURFER and thus the regional map along with the local map of the study area were prepared.

RESULTS AND DISCUSSIONS

A research study was conducted to develop ground water map of Peshawar selected sites of Peshawar. The results of the study are presented and discussed in the following sections.

Topography of the Study Area

The Topography of the study area varies with respect to location of sites selected. The slope is undulating towards east from Hayatabad. This whole surface is covered with consolidated deposits of silt, sand and gravel of recent geological times. The natural surface drainage flow is along the natural terrain while in the present study area the surface flow is passing through university campus. The surface materials from west to east is fine alluvial deposits of light and porous soil composed of a mixture of clay and sand. The type of soil is good for cultivation of various crops. The elevation of the area under study is about to be 358 m from mean sea level, with mean maximum temperature of 40 °C and mean minimum temperature of 25 °C in summer, while in winter mean maximum temperature limits to 18.35°C and mean minimum temperatures reaches to 4°C. The average annual rainfall based on 30 years data is about 400 mm (DCR Peshawar, 1998).

Development of Ground Water Mapping in Study Area

The detailed ground water maps of the study area were developed on the basis of water table depths calculated from survey out comes which were also conformed from the existing values, the detailed maps for each region including in the study area were prepared.

Groundwater Map of University Campus

Figure 2 shows the contour Map of the University Campus. The following map prepared by using Surfer Software shows that the groundwater flow throughout the university campus is towards the region of Pakistan Forest Institute (PFI) as the average elevation of water table recorded at PFI is 334 m while the water table near the Works Directorate is at an elevation of 339 m. The general groundwater level is 5 m higher in Works Directorate of Agriculture University than at the foot ball ground of PFI. Hence, the direction of flow is towards the foot ball ground. If the groundwater abstraction at PFI has been increased it will automatically drop the water level in Works Directorate by its increased potential difference.

Groundwater Map of Malakandhir Farm

Figure 3 shows the water map of Malakandhir Farm and Kacha Gahri area in the surrounding of warsak gravity irrigation canal. The groundwater flow pattern observed in various profiles surveyed at Malakandhir and Kacha Garhi show that the groundwater flow direction from warsak gravity irrigation canal is mostly towards the NPC (319 m) through from the IBG (323m) and Works Directorate of the AUP (334 m). The groundwater level at the Warsak Gravity Canal near Veterinary hospital is very high (359 m) from where it depletes towards the Military Farm (351 m). The impermeable layer of Clay content in Biotechnology and Professor Colony Profiles laterally obstruct the advective flow from different directions. However the professor colony due to its lowest groundwater level attracts the groundwater flow mostly towards its self.

Groundwater Map of Hayatabad

Figure 4 shows the detail map of Hayatabad groundwater flow in different directions. The contours developed with the help of Surfer software shows that the groundwater level at the position where Phase-4 by drain is separating from phase-3. The elevation of groundwater at this location has comparatively higher (346 m) than the rest of the points in Phase 3 such as Civil Quarters (339 m), Police Post (344 m), Ring Road Bridge (341 m). The ground water flow from Hajicamp, IM sciences and F-7 of Phas-7 are mostly contributing to the groundwater level of Behram Market where six tube wells are in operation constantly to supply water to a larger and extended area. The groundwater flow is faster and in greater amount. The open drains on both of its sides on the outer boundary of Phase-3 and the upper watershed areas outsides the ring road are contributing a lot amount of groundwater to phase-3civil quarters region at the north east of Hayatabad and the Tajabad township. The movement of groundwater and its amount is lower towards Phas-4. The eastern watersheds of regi lalma and kacha garhi are also contributing to the Behram market region where six public health tube wells are always in operation and continuously to the extended and population of Hayatabad

Groundwater Map of Study Area

Nearly 25000 acre of land surveyed for the study. The warsak gravity irrigation, three open main drains, 41 tube wells, 250 acre of agricultural land, most of the residential area have lot of water consuming zones for drinking purposes. The seepage from the warsak gravity irrigation canal is contributing a large amount for its left side to the groundwater of veterinary hospital area and through Military Agriculture Farm to Agriculture University Malakandhir Farm, Biotechnology institute, New Professor colony and Forest Institute region.

The seepage from the right side of the warsak gravity irrigation canal mostly reaches the groundwater of Phase-4 through kacha garhi area while at upslope its seepage reaches haji Camp in Phase-7 which contributes groundwater recharge for six tube wells in series at Behram Market. The other sources of recharge to Behram Market region are from F-7 in phase-7. The main open drain in F-7 mainly contributes to the groundwater of this zone. The groundwater from F-7through IM Sciences region reaches Behram Market region. The third source of recharge to the groundwater of Behram Market area is from the open drain at the outer eastern boundary of Hayatabad which also contributes to Phas-3 near police post and Civil Quarters. The civil Quarters of Phase 3 on its northern side is being contributed by the seepage from the warsak gravity irrigation canal. The contour map of regional groundwater flow is given in figure 5 below on the basis of that flow the critical zones are summarized as Behram Market in Hayatabad followed by civil Quarters in Phase-3. Furthermore the recharging zones identified were Warsak Gravity Canal and Eastern Boundary Drain. If the surrounding of Hayatabad like Regi Lalma, Kachi garhi, Taj Abad and other southern areas got developed, these will exploit the recharge from the warsak gravity canal then Hayatabad will face lot of Water Crisis specially Phse-3 & 4 in addition to Behram Market zones.

After the development there is the only option that is left to maintain the groundwater level of Hayatabad is from the artificial recharge from the run off of the main open drains within Hayatabad and its eastern boundaries. Hence the methods in processes of artificial recharge from the main open drains are needed to be explored or determined the different permeable layers below the ground surface. Hence Straithography needs to be developed to approach these sources to be recharged towards the critical zones of Hayatabad.

CONCLUSION AND RECOMMENDATIONS

The research study was designed to achieve the assigned objectives mentioned above which were achieved successfully as the results were cross checked with existing bore-hole logs and were matched up to good agreement.

- The highest value of water table was at PFI Nursery (19 m with respect to ground surface) Works Directorate (20 m with respect to ground surface) PFI Forest (22 m with respect to ground surface) while the lowest water table calculated was at Hayatabad most notable in Phase 7 Behram Market (92 m with respect to ground surface) IM Sciences (87 m) and F-7 (82 m with respect to ground surface), the water bearing strata calculated at all of the locations were sandy clay, sand and gravel with some clay components in small amount.
- The Groundwater map reveal that with some obstructions as clay and lateritic soils may resist the groundwater flow from one distinct region to another. The main open drain in phase 3 of Hayatabad is the main source for the whole region around. The seepage from the Warsak Gravity Canal is the second main source for the region of Military and Malakhandir Farms, NPC and IGB. The regional groundwater is mainly obstructed due the structural complexity of the soil strata. The phase 3 and phase 7 are the main user to exploiter the groundwater level in the area.
  - There should be a dense survey in the whole region to identify more sites of highest groundwater elevation.
  - Instead of natural surface flow and seepage, there should be some storage in the permeable zone or open dug wells towards in the usual reservoir.

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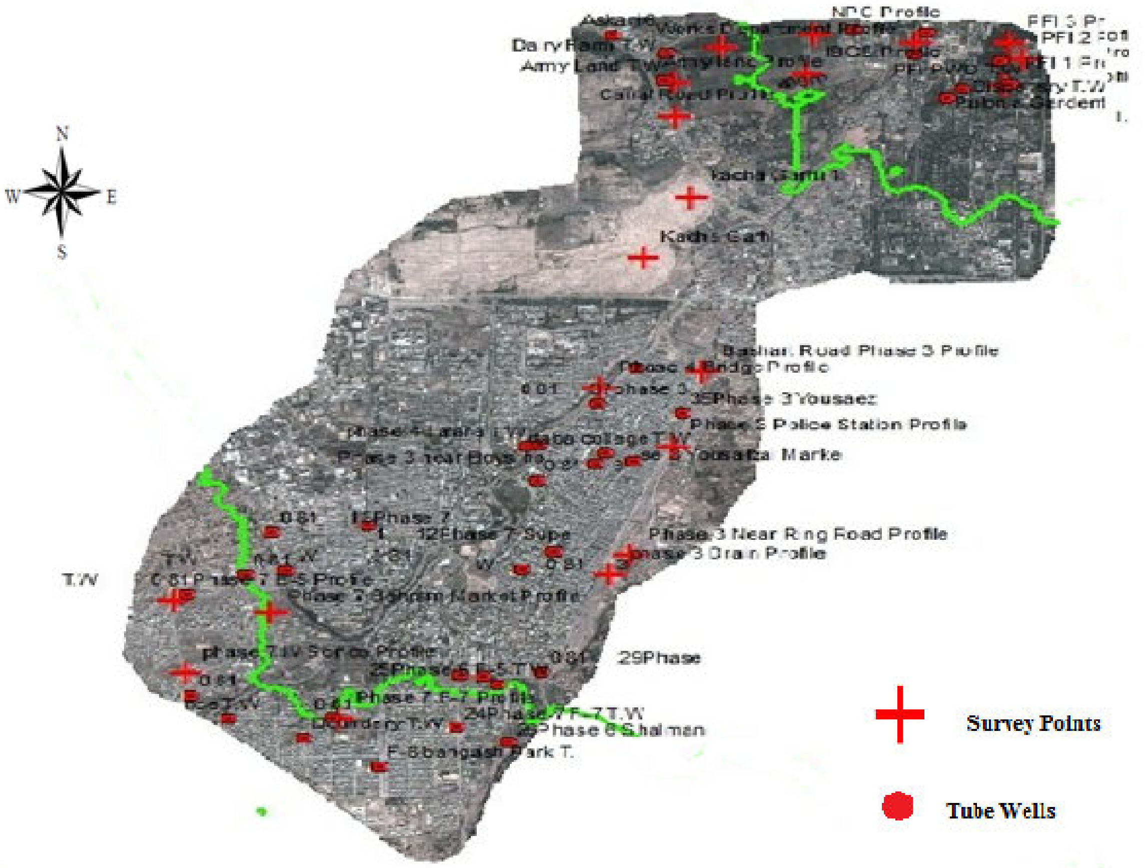

Figure 1Detailed Map of the Study Area

Table 1 Table for Geographical Positions of Different Locations Surveyed

Name of the Area		Name of the Site Surveyed	Latitude	Longitude
Pakistan Forest Institute (PFI) Profiles	Site 1	Forest Land	34° 1'1.36"N	71°29'10.08"E
	Site 2	Nursery Area	34° 1'16.17"N	71°29'12.13"E
	Site 3	Football Ground	34° 1'10.24"N	71°29'15.64"E
	Site 1	Works Directorate	34° 1'17.87"N	71°28'44.38"E
	Site 2	Professor Colony	34° 1'20.81"N	71°28'14.87"E
The University of Agriculture Profiles	Site 3	Biotechnology Land	34° 1'6.89"N	71°28'12.23"E
	Site 4	Malakhandir Farm	34° 1'16.91"N	71°27'47.46"E
	Site 5	Military Farm	34° 1'4.71"N	71°27'33.14"E
	Site 6	Veterinary Hospital	34° 0'52.91"N	71°27'33.09"E
Kacha Garhi Profiles	Site 1	Kacha Garhi near A	34° 0'24.20"N	71°27'36.90"E
	Site 2	Kacha Garhi near B	34° 0'3.13"N	71°27'22.01"E
	Site 1	Phase 4 Drain	33°59'17.41"N	71°27'7.55"E
	Site 2	Phase 3 Civil Quarters	33°59'22.37"N	71°27'37.78"E
	Site 3	Phase3 Police Post	33°58'56.20"N	71°27'27.96"E
Hayatabad Profiles	Site 4	Phase 3 Ring Road	33°58'18.15"N	71°27'14.02"E
	Site 5	Phase 3 Drain	33°58'11.55"N	71°27'8.07"E
	Site 6	Phase 7 F-7	33°57'23.41"N	71°25'45.14"E
	Site 7	Phase 7 IM Sciences	33°57'40.00"N	71°25'2.14"E
	Site 8	Phase 7 Haji Camp	33°58'5.90"N	71°25'0.05"E
	Site 9	Phase 7 Behram Market	33°58'0.42"N	71°25'27.82"E

Table 2 Latitude Longitude and Ground Water Elevation of Each Profile

Name of Site	Lat(N)	Long(E)	Water Table Depth	Lat(m)	Long(m)	Elevation	Ground Water Elevation
Site 1(PFI)[1]	34° 1'1.36"	71°29'10.08"	22	1087710	3064820	356	334
Site 2	34° 1'10.24"	71°29'15.64"	23	1087990	3064950	353	330
Site 3	34° 1'16.17"	71°29'12.13"	19	1088170	3064860	358	339
Site 1(AUP)[2]	34° 1'17.52"	71°28'44.60"	20	1088170	3064150	359	339
Site 2	34° 1'6.89"	71°28'12.23"	37	1087830	3063330	360	323
Site 3	34° 1'20.81"	71°28'14.87"	41	1088260	3063380	360	319
Site 4	34° 1'16.91"	71°27'47.46"	28	1088120	3062690	368	340
Site 5	34° 1'4.71"	71°27'33.14"	22	1087730	3062330	373	351
Site 6	34° 0'52.91"	71°27'33.09"	19	1087370	3062340	378	359
Site 1(KG)[3]	34° 0'24.20"	71°27'36.90"	24	1086490	3062470	375	351
Site 2	34° 0'3.13"	71°27'22.01"	26	1085830	3062110	378	352
Site 1(HD)[4]	33°59'22.37"	33°59'22.37"	46	1084590	3062550	385	339
Site 2	33°58'56.20"	71°27'27.96"	48	1083770	3062330	392	344
Site 3	33°59'17.41"	71°27'7.55"	41	1084410	3061780	387	346
Site 4	33°58'18.15"	71°27'14.02"	65	1082380	3061860	406	341
Site 5	33°58'11.55"	71°27'8.07"	37	1082590	3062010	411	374
Site 6	33°57'23.03"	71°25'45.44"	71	1080810	3059810	429	358
Site 7	33°57'39.38"	71°25'2.16"	87	1081310	3058660	437	350
Site 8	33°58'5.90"	71°25'0.05"	82	1082100	3058580	436	354
Site 9	33°58'0.42"	71°25'27.82"	92	1081970	3059300	427	335

Table 3 Resistivity Values for Some Common Geological Formations (Anthony *et al.* 2006)

Material	Nominal Resistivity (Ω-m)
Quartz	$3 \times 10^2 – 10^6$
Granite	$3 \times 10^2 – 10^6$
Granite (weathered)	30 – 500
Consolidated shale	$20 – 2 \times 10^3$
Sandstones	200 – 5000
Sandstone(weathered)	50-200
Clays	$1 – 10^2$
Boulder clay	15 – 35
Clay (very dry)	50 – 150
Gravel (dry)	1400
Gravel (saturated)	100
Lateritic soil	120 – 750
Dry sandy soil	80 – 1050
Sand clay/clayed sand	30 – 215
Sand and gravel(saturated)	30 – 225
Mudstone	20-120
Siltstone	20-150

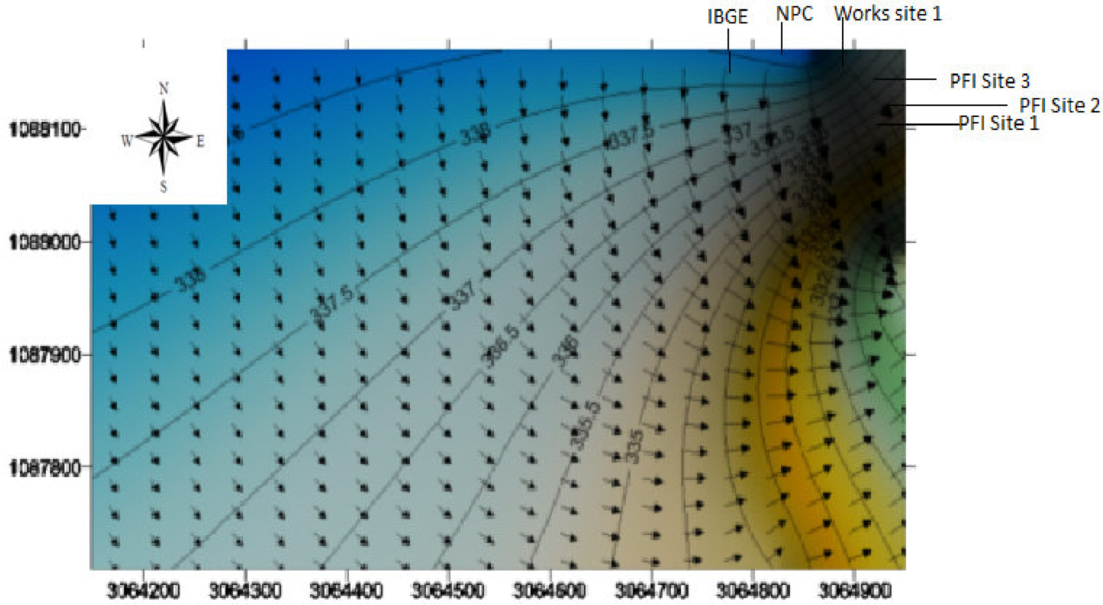

Figure 2Contour Map of University Campus

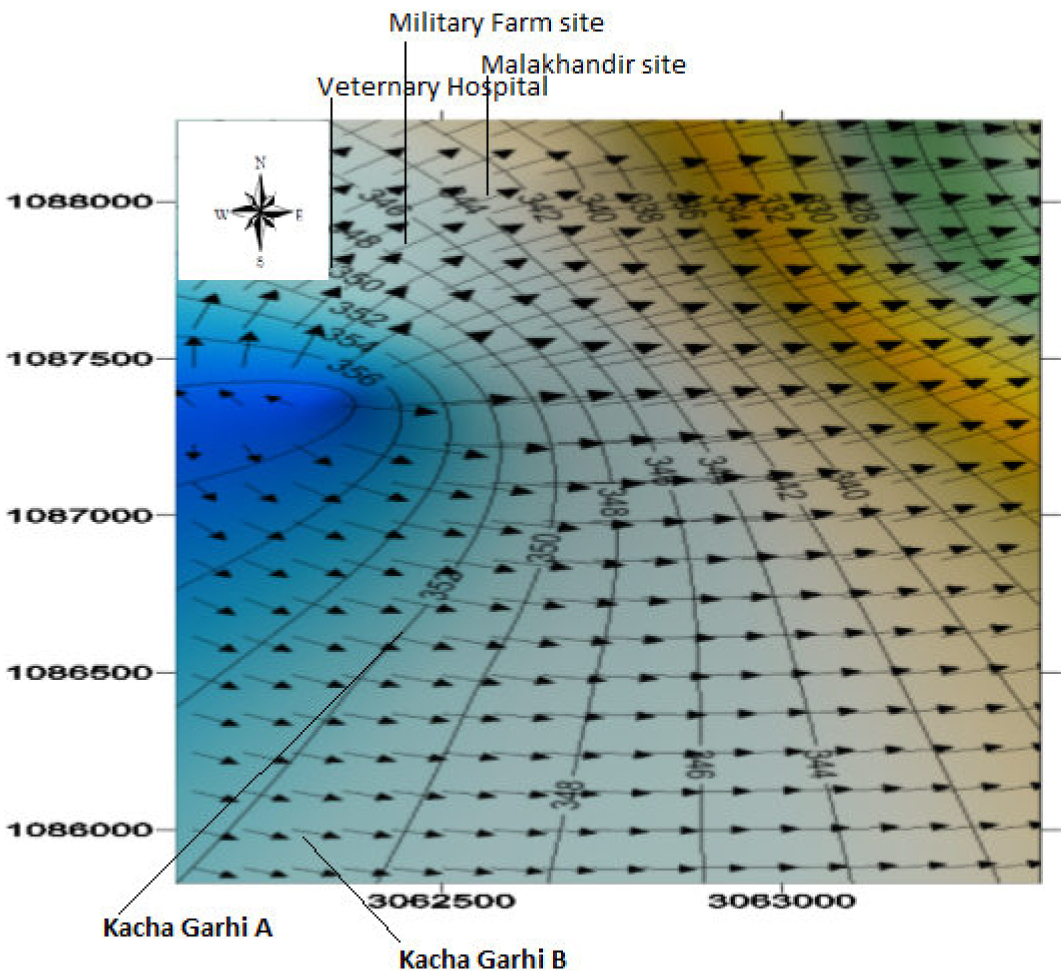

Figure 3 Contour Map of Malakandhir

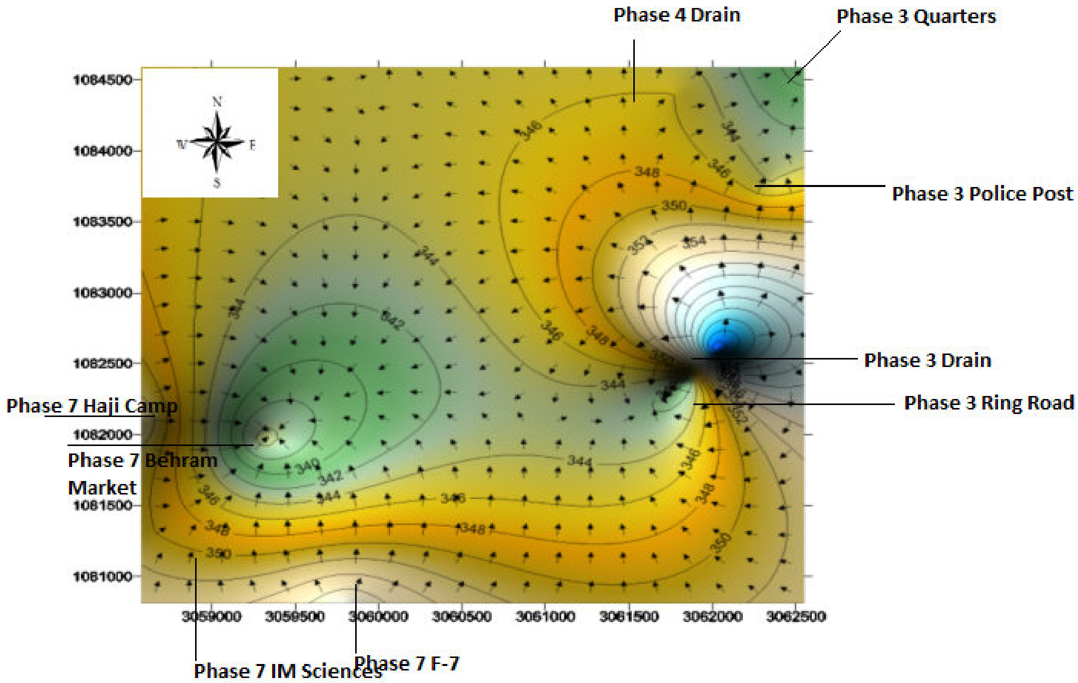

Figure 4 Groundwater Map of Hayatabad

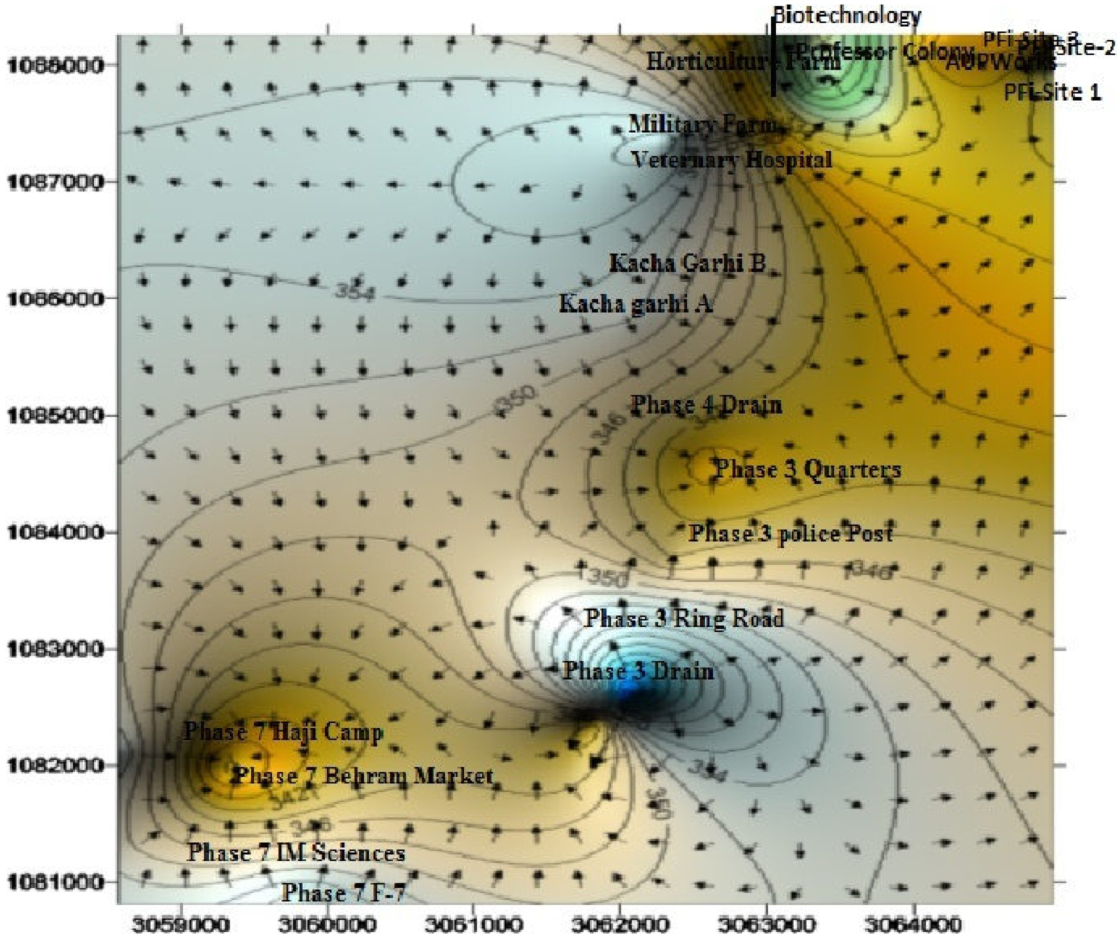

Figure 5Groundwater Map of the Study Area